LAKE CITY BRIDGE
(Marsh Rainbow Arch Bridge)
(Raccoon River Bridge)
(Rainbow Bridge)
Iowa Bridges Recording Project
Spanning North Raccoon River,
2.7 miles S.W. of Lake City
Lake City Vicinity
Calhoun County
Iowa

HAER No. IA-46

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REDUCED COPIES OF MEASURED DRAWINGS

WRITTEN HISTORICAL & DESCRIPTIVE DATA

HISTORIC AMERICAN ENGINEERING RECORD
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LAKE CITY BRIDGE
(Marsh Rainbow Arch Bridge)
(Raccoon River Bridge)
(Rainbow Bridge)

HAER No. IA-46

Location:	Spanning the North Raccoon River, within Rainbow Access Park, 2.7 miles southwest of Lake City, Calhoun County, Iowa. UTM: 14.730310.4812580 USGS: Rock Rapids, Iowa quadrangle (7.5 minute series, 1971)
Date of Construction:	1914
Designer:	James B. Marsh, Des Moines, Iowa
Contractor:	Iowa Bridge Company, Des Moines, Iowa
Present Use:	Pedestrian Bridge
Significance:	The Lake City Bridge is an early and outstanding example of James B. Marsh's Rainbow Arch design. Unlike most reinforced-concrete arch spans in which the roadway rested on top of the arches in standard configuration, the Marsh design suspended the deck from the arch that sprang from piers and extended above the roadway. Its distinctive "rainbow" profile popularized this type of bridge, and hundreds were constructed in the 1910s, 20s, and 30s, primarily in the Midwest. The Lake City Rainbow Arch, constructed in 1914, was his first experiment in applying this patented design to a multiple span structure.
Historian:	Juliet Landler, engineer, August, 1995
Project Information:	This document was prepared as part of the Iowa Historic Bridges Recording Project during the summer of 1995 by the Historic American Engineering Record (HAER). The project was sponsored by the Iowa Department of Transportation (IDOT). Preliminary research on this bridge was performed by Clayton B. Fraser of Fraserdesign, Loveland, CO.

During the 1920s, people came to Calhoun County, Iowa from as far away as Chicago to visit Rainbow Resort, a 19 acre vacationland situated on the banks of the North Raccoon River. The resort took its name from the historic site on which it was built, known locally as Rainbow Bend. Here on the river's edge, the county's founding fathers first camped after paddling up the Raccoon River in the 1850s. The resort boasted a wide array of activities: dancing, music, games, swimming, and even ice skating. There was a grocery store, a hotel, a clay pigeon shooting gallery, and a ferris wheel. A generator supplied electricity, and the living quarters stood on stilts as a precaution against flooding.[1] At the heart of this bustling complex, an unusual reinforced-concrete bridge spanned the river. It was called, not surprisingly, Rainbow Bridge. This name, however, had origins not in its locality, but in its patented design.

As was common for longer concrete bridges, Rainbow Bridge was comprised of multiple arches, each having spans of eighty feet. Builders of the earliest stone bridges had learned that the arch was particularly efficient when loaded in compression, transmitting forces from the roadway above directly into the foundations. The design of Rainbow Bridge, however, did not follow the standard configuration. Instead of the roadway sitting on top of the arches, its arches extended above the roadway and carried the floor in suspension through the use of hangars. These tensile elements were heavily reinforced and spaced at regular intervals. This novel configuration created a distinctive profile, and the nickname "rainbow arch" was coined for this bridge type ever before one was built at Rainbow Bend.

Although Rainbow Bridge served as the centerpiece for the resort, it had not been designed for this purpose. In fact, it had been constructed in 1914, several years before the resort was even founded.[2] At this time farms occupied the surrounding property, and the bridge served as an important crossing on a major market road. Two miles to the north lay Lake City, one of the most important trading centers for the county. Rainbow Bridge replaced a pinned Pratt through truss which had been

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[1]Calhoun County Historical Society. *Calhoun County History*. Rockwell City, IA. 1982. p.11.

[2]Surprisingly, very little documentation about the resort exists and the date it was established can only be estimated as sometime around 1920.

fabricated by the King Iron Bridge Company of Cleveland, Ohio in 1892.[3]

Lake City was established in 1856, making it the oldest town in Calhoun County, and served as county seat until 1876[4]. Like many Iowa towns, Lake City began as a mill town. The first grist mill was built in 1855 on the Raccoon River not far from Rainbow Bend. Soon after, a sawmill was added. When the area surrounding the North Raccoon River was first settled, the plains were filled with many swampy ponds and small lakes. Hence, the early residents named their settlement Lake City. Once drained, the fields proved fertile, and the early farmers began a prosperous trade in wheat.[5] By the twentieth century, they had diversified their crops and were raising livestock. In 1900, the township of Jackson averaged 65 cattle per square mile, and Lake City had become a thriving small community.[6]

Towards the end of the nineteenth century, Lake City flourished as local leaders worked to improve the town's amenities. In 1893, the town replaced the public well with a piped water system. In 1894, the streets were electrified. In 1899, a construction boom hit the downtown when the local bank teamed up with the farmer's cooperative to build the Townshend Block. The Townshend Block housed the bank, commercial properties, professional offices, public meeting rooms, and an opera hall. In 1904, a new high school was built, and in 1908, Andrew Carnegie endowed the local library association with $7,500 for the construction of a public library. In the first years of the twentieth century, sixteen doctors were living in town, and Lake City had become a regional medical center. Other industries soon followed, one of which was a manufacturing company specializing in concrete products. Lake City always had been progressive in its use of this modern building material, pouring is first concrete sidewalk in 1891. A few brick sidewalks persisted until being outlawed in 1915 by city officials who

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[3]Fraserdesign, *Iowa Historic Bridge Inventory*, Structure no. 090830, 1992.

[4]Lake City Historic Preservation Committee. *Lake City History*. 1987. 9.

[5]Ibid. p.10.

[6]Ibid. p.59.

passed an ordinance requiring all sidewalks to be constructed of concrete.[7]

Since concrete had become the building material of choice in Lake City, it was not surprising that county supervisors chose to replace the metal truss at Rainbow Bend with a concrete bridge, even when they had received a lower bid for a steel structure.[8] During the previous year, the Board of Supervisors had requested designs for the replacement bridge from both the Iowa State Highway Commission and the Marsh Engineering Company of Des Moines. In January 1914, the Highway Commission submitted plans for a three-span pony truss bridge on concrete piers and abutments. At about the same time, James B. Marsh, the founder and principal of Marsh Engineering, completed his plans for the reinforced-concrete triple span bridge which he had based on the "rainbow arch" patent he had received two years previously.[9] In accordance with a recent law, the county first sought the Highway Commission's approval on Marsh's plans before soliciting bids on both designs in March 1914.[10] Bids on the steel structure were competitive, ranging from $9,700 to $11,890, but did not sway the Board of Supervisors away from their original intention of building a concrete bridge.[11] They awarded a $10,970 contract to the Iowa Bridge Company for the construction of the concrete-steel bridge, not including the cost of piling.[12] County officials were confident this bridge would save them money in the long run, requiring less maintenance and no painting. The local paper declared, "it will be a durable and permanent structure and decidedly ornamental, and .. the cost will probably not be any greater than for a

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[7]Lake City Historic Preservation Committee, *Lake City History*. 58-60.

[8]"A Handsome Bridge." *Lake City Graphic*. April 30, 1914.

[9]Fraserdesign. *Iowa Historic Bridge Inventory*. Structure no. 090830, 1992.

[10]In an effort to standardize county bridge and road construction, a state law, passed in 1913, gave the Highway Commission the authority to oversee all new bridge construction in the counties. MacDonald, Thos. "Bridge Patent Litigation in Iowa" *The Iowa Engineer*. Vol 18., No. 4. Jan 1918. 117-127.

[11]"A Handsome Bridge." *Lake City Graphic*. April 30, 1914.

[12]Calhoun County Supervisors' Minutes. Book 7, p. 374 (Feb. 18, 1914) and p.392 (Apr. 21, 1914).

steel bridge with a concrete floor."[13] And with the construction of Rainbow Bridge, Lake City would remain on the cutting edge since, "it was freely predicted that the concrete bridge is certain to become a universal favorite."[14]

Construction proceeded quickly, and Rainbow Bridge was completed in October of 1914. Sixteen men were engaged in its erection: 14 laborers, 1 timekeeper, and 1 foreman. The foreman, C.A Johnson, was a young engineer and recent graduate of Iowa State College of Agriculture and Mechanic Arts (now Iowa State University). One hundred cubic yards of gravel was collected on a riverbank 1/4 mile away, while the other materials were shipped by railroad to the building site. Three carloads of steel and five carloads of cement were consumed in the construction. A storage shed was built to house the cement, and three gasoline-powered pumps and a steam hoist were used in the construction process. The new bridge location had been moved 29' upstream from the old site.[15]

By 1914, two rainbow arches already had been built in Iowa. A third arch had been planned for Yellowstone National Park. The bridge outside Lake City would be the fourth constructed using the patented design. Nevertheless, Marsh still considered this bridge an experiment. "This bridge is being made as a sample," the local paper reported, for this contract marked his first opportunity to design to a multiple span Rainbow Arch.[16]

After patenting the Rainbow Arch design in 1912, Marsh promoted it extensively across the country, touting it as the bridge of the future. This type of bridge was more durable and economic than steel bridges, he enthused, and aesthetically superior to all other types, concrete, steel, or wood.[17] In Lake City, he unabashedly predicted, "it will stand as long as time unless greater calamities than have ever been known befall it."[18]

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[13]"A Handsome Bridge." *Lake City Graphic*. April 30, 1914.

[14]Ibid.

[15]"New Bridge over 'Coon." *Lake City Graphic*. August 27, 1914.

[16]Ibid.

[17]Fraserdesign. *Iowa Historic Bridge Inventory*. Structure no. 090830. 1992.

[18] "New Bridge over 'Coon." *Lake City Graphic*. August 27, 1914.

James Barney Marsh was a well respected engineer in Iowa. Born in North Lake, Wisconsin in 1856, Marsh moved to Fredericksburg, Iowa to attend preparatory school. Once Marsh arrived in Iowa, he never left, continuing his education at Iowa State College of Agriculture and Mechanic Arts in Ames. In 1882, he obtained a bachelor degree in mechanical engineering. Soon after he began his professional career in the Des Moines office of King Iron Bridge Company where he designed, marketed, and supervised the construction of truss bridges throughout the state. He worked in this capacity for five years. In 1887 he accepted an offer to head the Des Moines office of the Kansas City Bridge and Iron Company. Two years later, Marsh moved backed to King Iron Company to become its general western agent and contracting engineer, a position he kept for seven years.[19] Thus Marsh probably supervised the installation of the 1892 pinned Pratt truss at Rainbow Bend. In 1896, Marsh left King Iron to start his own consulting engineering practice. In 1904, he expanded his business to include bridge building, calling his newly incorporated organization, Marsh Bridge Company. He reorganized the firm again in 1909, changing the name to Marsh Engineering Company.

During his years at King Iron Bridge Company and the Kansas City Bridge and Iron Company, Marsh had become an expert in metal truss construction. However, soon after he struck out on his own, his interest turned to concrete. Already by 1903, Marsh had designed two concrete bridges: one for Kankakee, Illinois, and another at Kenosha, Wisconsin. Typically, Marsh would construct bridges from his own designs, but on more than one occasion he bid on other bridge designers' plans.[20] During the 1910s, Marsh won several commissions for some of Iowa's major city spans: the Walnut Street and Court Avenue Bridges in Des Moines, the Fourth Street Bridge in Waterloo, and the Second Avenue Bridge in Cedar Rapids. Marsh also designed smaller projects for the Iowa State Highway Commission.[21]

Marsh was certainly not the first designer to create the famous "rainbow" profile by suspending the floor deck from the arches extending overhead. German designers of metal bridges

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[19]"A Good Bridge Man." *The Saturday Review*. Des Moines. Feb. 11, 1893.

[20]In 1905 Marsh was awarded the contract to build a bridge in Trinidad, Colorado using a design of Daniel Luten, an archrival who would sue Marsh in 1912 for patent infringement. (HAER no. IA-29, Fraserdesign, p.4).

[21]HAER Report No. IA-29, Fraserdesign, p.4.

frequently had used this form to span great distances in the 1880s.[22] In America, similar bridges existed, although not quite as large. Nevertheless, in an era when the flat slab was the most popular type of concrete bridge, Marsh's approach represented a radical alternative. In his patent application, he stated:[23]

> "Broadly speaking the object of the present invention is, to construct an arch bridge of reinforced-concrete in such manner as to permit a limited amount of expansion and contraction both of the arches and of floor which are, of course, the longest members of the bridge."

He went on to describe the bridge in greater detail, summarizing its innovative features:

1. In a bridge, the combination with the abutments, parapets along the side wall thereof, a pair of arches springing from points in the abutments below the upper edges of their walls, and beams integrally connecting said arches at two points between the abutments; of a floor of reinforced-concrete whose extremities rest slidably on the front walls of said abutments and whose body overlies said beams and floor in slidable contact with each other, the endposts standing inside those on the parapets, and rails connecting the posts on the floor.

2. In a reinforced-concrete bridge, the combination with the abutments, a pair of arches integral with and springing from points low in the inner walls of said abutments, and two beams integrally connecting said arches at points adjacent to the abutments; of hangers depending from the arches in pairs between said beams, cross ties integrally connecting the lower ends of said hangers in pairs, a floor consisting of a depressed body and raised curbs along its edges, the body formed integral with said ties and slidably mounted on said beams and parapets and the curbs formed integral with said hangers but separate from said arches, flat wear plates secured respectively to said beams and to the floor where it crosses them, and a filling upon the body of the floor between its curbs.[24]

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[22] Henry Tyrrell, *History of Bridge Engineering*. Chicago. 1911. 331-336; Hans Wittfoht, *Building Bridges*. Beton-Verlag, Dusseldorf. 1984. 126-9.

[23] Marsh, James B. *Patent No. 1,035,026 - Reinforced Arch Bridge*. Aug 6, 1912.

[24] Ibid.

This first patent was for a single span bridge of medium length, although Marsh outlined provisions in the application for the construction of larger bridges of this type. A broader bridge could be made by setting three or four arches side by side "in strict parallelism."[25] A longer bridge could be made by placing the arches in series, supported by piers, which would be treated in the same fashion as the abutments. The construction drawings of the bridge at Lake City show that Marsh did make a few minor revisions in his metal connection specifications in the two years after he received the patent, but essentially Rainbow Bridge follows his original conception.[26]

Rainbow Bridge has a total length of 271', comprised of three spans plus piers, and a curb-to-curb width of 18'. The arches begin 8'10" below the deck, and then extend 11'3-1/2" above it.[27] The arch ribs measure 20" thick, tapering from a depth of about 60" at the piers to a depth of 24" at their crowns.[28] Hangers suspending from the arches are spaced at intervals averaging of 7'10-1/2".[29] Twenty-four piles were driven under each abutment, while twenty-seven were driven under each pier.[30]

Encased in the concrete is a heavy steel skeleton composed largely of riveted angle and flat stock. Each arch rib is reinforced with four steel angles (2-1/2" x 2-1/2" x 3/8"), laced together with steel bars (1-1/2" x 1/4")forming a box-lattice girder, and spliced with steel plates (1/4"). Each hanger also is reinforced by four angles of slightly smaller dimensions (2" x 2" x 1/4"), and connected only by plates.[31] Four crossrods (1-1/8" dia.) run longitudinally through each

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[25]Ibid.

[26]Two sheets of the original construction set of drawings are on file in the Calhoun County Engineer's Office. General details are shown on one sheet, loading and temperature stress calculations are shown on the second.

[27]*Lake City Graphic*. "New Bridge over 'Coon." August 27, 1914.

[28]HAER field measurements, Iowa Historic Bridge Recording Project, June 6, 1995.

[29]Ibid. This measurement agrees with the construction drawings.

[30]*Lake City Graphic*. "New Bridge over 'Coon."

[31]Construction drawings.

floor beam and tie, the two upper bars having depressed centers to resist bending stresses. U-bars, or stirrups, were placed around the rebar to ensure against shear failure. Marsh made a distinction between two types of transverse members supporting the deck which he refers to as beams and ties. The beams, which have sections 18" wide and 20" deep, run under the floor bed connecting each pair of arch ribs. The ties, which measure 12" by 25", connect pairs of the hangers, and were cast integrally with the floor slab.

The idea behind the Marsh patent hinged on the difference between how the two supporting elements were detailed. The floor slab rested on the beams, but was not fixed to them. Metal plates attached to the their surfaces allow the floor slab to slide over the beams. Since the floor slab had been cast together with the ties and hangers, its movement is related to the movement of these elements. However, the floor slab can move independently from the arches. Thus, Marsh's objective was fulfilled, and the two longest members could expand and contract free from each other. In the early days of reinforced-concrete technology, temperature induced stresses were a major concern since they seemed to have great effects, but were not yet understood. Marsh was one of many engineers preoccupied with the issue, and he continued to refine his rainbow arch design to reduce temperature stresses for years after he obtained his patent. In 1921, he received another patent for improvements in the hanger connections which allowed these elements to expand at different rates.[32]

Another advantage of the rainbow design was revealed in the construction process. Rainbow arches typically followed a standard sequence for concreting: the piers and the abutments were poured first, the arch ribs and floor beams second, the floor ties and slab third, the coping and hangers fourth, and finally the slotted guardrail fifth. Between the first two steps, the steel skeleton of reinforcement was assembled and connected with rivets. This structure was sufficiently strong to support the formwork for the remaining construction, and thus eliminated the hazard of having high waters wash out the falsework. Once completed, the Rainbow Arch also demonstrated superior flood performance since the clearance between the river and bottom of the road bed was greater than most other bridge types.

In a extensive promotional campaign, Marsh successfully marketed these attributes and its aesthetic appeal. Hundreds of rainbow

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[32]Marsh, James B. *Patent no. 1,388,584 - Arch Bridge Construction*. Aug 23, 1921.

arches were constructed by his company, and by associates such as the Westcott Engineering Company of Chicago. A survey in Kansas calculated that 73 Marsh arches were built in the state between 1917 and 1940.[33] Dozens were also constructed in Iowa.[34] The vast majority of these bridges were single span structures, although several other significant multiple span bridges were built elsewhere. Marsh's vision culminated in the Fort Morgan Bridge in Colorado, an 11-span arch built in 1923, and in the Cotter Bridge in Arkansas, a nine-span arch built in 1930.

As more sophisticated techniques for reinforcing slabs and girders were developed in the 1930s and 40s, construction of concrete arch bridges waned. Despite Marsh's boast of durability and permanence, the majority of his bridges have disappeared or become inoperable in recent years, having fallen victim to rusting and spalling. Only Eleven rainbow arches remain in Iowa. Lake City is unique in being the only triple span in the country.

Although innovative, the Marsh Rainbow Arch is not an example of outstanding structural engineering. The reinforced-concrete bridge did indeed become "the universal favorite," as the Lake City newspaper had predicted in 1914. With modern methods of reinforcing, it proved to be the most economical. However, Marsh's structural armature, which he encased in concrete, set no precedent for these modern methods. In fact, quite the opposite is true: with its stiff steel stock and riveted plate connections, this system of reinforcement was more reminiscent of many metal bridges the designer had constructed in the early days of his profession. Marsh was accurate in his claim that his Rainbow Arch design required less steel than competitive metal truss designs, but still its use was excessive and inefficient. Marsh's Rainbow Arches were really not much more than metal frames enveloped in concrete.

Rainbow Bridge has fared better than most of Marsh's arches. Spalling only in spots where automobiles collided years ago, the structure is still sound. The crossing was closed to vehicular traffic in 1985 due to its narrow width and dangerous curved approaches. The only vestige of the lively resort, Rainbow Bridge remains popular with the community. Fisherman, campers,

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[33]Jackson, Donald. *Great American Bridges and Dams*. The Preservation Press - National Trust for Historic Preservation. Washington D.C. 1988. 207-208.

[34]Fraserdesign. *Iowa Historic Bridge Survey*. 1992.

and especially the county's young population regularly come to enjoy its peaceful setting in Rainbow Bend Access Park.

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This appendix is an addendum to a 13-page report previously transmitted to the Library of Congress.

APPENDIX: ADDITIONAL REFERENCES

Interested readers may consult the Historical Overview of Iowa Bridges, HAER No. IA-88: "This historical overview of bridges in Iowa was prepared as part of Iowa Historic Bridges Recording Project - I and II, conducted during the summers of 1995 and 1996 by the Historic American Engineering Record (HAER). The purpose of the overview was to provide a unified historical context for the bridges involved in the recording projects."